How can a research program influence public policy? Evaluating a decade of research impact using an evidence-based theory of change

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ABSTRACT

This study proposes the systematic empirical development of a theory of change for both planning and evaluating research impact on public policy. This use of theory of change is underdeveloped as a retrospective research impact evaluation method, capable of covering long timespans. Here, we assess impact at the level of a UK water research program with a 10-year timeframe. We developed a program-level theory of change from overlapping data sources. This involved integrating inside-out and outside-in perspectives on impact processes through survey, interview and focus group-style participatory workshops to triangulate a model of policy influence. The result was a triangulated theory of change, refined through an iterative process. This method offers an adaptable evaluation framework that can also provide a robust basis for planning future research impacts. The findings underscore the importance of considering multiple perspectives and evidence sources in understanding research impact pathways, contributing to more effective and impactful research strategies in policy domains. The study's 10-year scope also shows the potential for evidence-based theories of change to explain some of the long-term, complex dynamics that enable research to influence policy.

1. Introduction

As funders and governments need evidence of societal benefits from research investments, focus has shifted from merely demonstrating impact to understanding the mechanisms driving it (Reed et al., 2021). This shift highlights the importance of evidence that can link impacts and specific research projects. This evidence can be useful for funders and research performing institutions, providing formative feedback for future impact generation (Coryn et al., 2011; Funnell et al., 2011; Jensen et al., 2021). As a result, there is growing interest in tools such as logic models and theory of change (ToC) to plan research impacts in an explicit way (De Silva et al., 2014; Marchal et al., 2012). However, conventional approaches to ToC development are typically speculative and unsystematic (Vogel, 2012), raising risks associated with overly simplistic causal models (Stein and Valters, 2012), missing critical factors and mistaken assumptions (James, 2011) (Rogers, 2008). At the same time, there is a need for useful, robust frameworks for retrospective impact evaluation, particularly when long timeframes are involved. In this article, we show how an empirically-validated ToC (i.e., an 'evidence-based theory of change') can deliver both refined impact planning and an effective impact evaluation.

Developed by Weiss (1995), a ToC outlines a project's expected progression to specific long-term impacts via a logical sequence of inputs, outputs, and intermediate outcomes (Vogel, 2012). Typically used for project planning, ToC identifies a process to reach intended impacts, considering assumptions about the process and contextual factors that might influence the delivery of impact, usually presented in a diagram with accompanying narrative (Vogel, 2012; Andersen, 2004). It is then used to design a theory-driven impact plan, including indicators of progress towards the intended impact. This tool, and associated internal dialogue, provides formative feedback that can guide future impact generation activities (see Claus et al., 2023) for guidance on coordinating the ToC design process in transdisciplinary research contexts). The capacity for ToC to represent complex causal relationships from intervention to impact (Breuer et al., 2018) makes them particularly well-suited to the planning of impacts from research, which tend to be highly complex, often incorporating significant time lags and multiple confounding factors that make it challenging to trace attribution from research to impact (Reed et al., 2021). As such, many theory-based evaluation approaches suited to transdisciplinary research initiatives that intervene in complex systems (e.g. contribution analysis, outcome mapping, outcome evaluation) draw on ToC as an analytical framework (Belcher et al., 2020).

Other impact planning techniques include logic models, realist

evaluation (Pawson and Tilley, 1997), participatory systems mapping and contribution analysis. Unlike logic models, ToC makes explicit the causal pathways through which change is expected (De Silva et al., 2014), and specifies the causal pathway in significantly greater detail to realist evaluation (Marchal et al., 2012). ToC simplifies the complexity of participatory systems maps, providing greater clarity on the pathways to change (see Wilkinson et al. 2021 for guidance on how to integrate these two methods). In common with contribution analysis (Morton, 2015), the ability of ToCs to identify key factors contributing towards or inhibiting impacts, makes them an ideal tool to enable the adaptation of existing pathways to impact and enhance future practice.

A key challenge with the practical application of impact planning concepts such as ToC and logic models is that they are often armchair exercises undertaken by one or more people inside of an organization (Harries, Hodgson, and Noble, 2014, p.5). In practice, a diverse range of relevant parties inside and outside of the organization are rarely involved in ToC development (Taplin and Clark, 2012, p.3). It is even more rare to have ToC development undertaken in a systematic, structured way that clearly relates the evidence from diverse relevant parties to the details of the ToC (Rogers, 2014). And it is even rarer still for ToCs to be refined iteratively over time based on emerging evidence, despite recognition among experts that there should be "regular review and updating" of ToCs based on empirical evaluation of impact pathways (CGIAR, 2012; Apgar et al., 2020).

Indeed, to date, there are few examples of ToCs aimed at guiding impact planning that include systematic empirical data collection and analysis, or triangulate external and internal perspectives (such as those done by USAID,2018; CARE International, 2016; World Bank, 2013). In the project that is the focus of this paper, we developed an empirically validated ToC with the aim of prospectively guiding impact planning, based on a retrospective analysis of previously generated impacts. This ToC work identified factors that had contributed towards the generation or inhibition of impact, to make recommendations for future programs of research that could draw on these lessons to drive greater impact from research. This systematic, empirical approach to ToC development can, in principle, be undertaken on a purely retrospective basis to evaluate impacts, or on prospective basis, using evaluation insights to plan future impact generation activities. Here, we retrospectively mapped impacts arising from Scotland's Centre of Expertise for Waters (CREW), to generate recommendations for the future design of a program of activities to generate impact. CREW is a Scottish Government-funded partnership between the James Hutton Institute, Scottish Higher Education Institutes and Research Institutes.

For the purposes of the ToC, impacts were defined as demonstrable changes or perceptible new outcomes or benefits to individuals, groups, organizations or society linked to research, not including academic contributions to the research literature (Reed et al., 2021). In this case, the retrospective ToC analysis was designed to inform the future work of this research program, drawing on an evidence-based understanding of what works and why in their efforts to deliver policy impacts.

2. Methods

At the end of two five-year research program funding cycles, the CREW research center commissioned an external team of social scientist evaluators to conduct a strategic impact review of its work until that point, and disentangle the factors within its operations that result in (or obstruct) projects having broad and/or significant impacts. The ultimate aim was to learn evidence-based lessons to inform practice in the next cycle and enhance the research program's future impact. This article is based on part of this impact evaluation work, and is co-authored by a mix of external evaluators and one member of the internal program staff.

2.1. Background and context

The focus of this study is a research center based in Scotland, set up as a 'center of expertise' for water.

> "Centres (of expertise) were established in response to Scottish Government's need for a mechanism which offered rapid and easy access to high calibre scientific evidence and advice. The aim was to create virtual centres which would bring together partnerships or networks of established research experts from a range of research organisations and which would be able to provide coordinated evidence and advice on demand". (Ferrier et al., 2022)

This center operates as a knowledge and funding broker for research on water in Scotland, connecting government departments and agencies with researchers to answer important questions to inform public policy and best practice. Funded through the Rural and Environment Science and Analytical Services (RESAS) division of the Scottish Government, the research center coordinates programs of research over five-year cycles for a range of public organizations, including Scottish Government, the Scottish Environment Protection Agency (SEPA), NatureScot and Scottish Water, organizations that aim to protect and enhance Scotland's water environment. The center's role in coordinating these program cycles focuses on bolstering scientific research capacity and advice for water and related environmental policy in Scotland (Ferrier et al., 2022).

Typically, the project development process for this government-funded research program goes through a four-stage process. This starts with (Stage 1) an organization approaching research program staff with a request for a project, rooted in a need for knowledge, guidance or tools to solve or understand practice or policy-based problems. Project requests are strategically prioritized by research program staff and relevant policy and regulatory organizations alongside a multi-agency consultation and prioritization process.

If selected, a project will undergo (Stage 2) a pre-project co-construction phase assembling key players including a project manager from the research program, a project steering group with policy/regulatory team members from relevant public organizations and a research team. The research team is typically formed by recruiting from universities and research institutes through an open funding call. In the pre-project construction phase, the research team, after being selected via the open funding call, proposes a scientific approach that aligns with the policy asks outlined by the project steering group. This model means the research program's co-construction process does not involve researchers from the start: This is because of the legal necessity of having an open tender process for recruiting the research team. In this procurement phase, pre-contract meetings are typically conducted to address final questions and discuss approaches. At this stage, the research team's input can lead to modifications in the project specification and/or contract.

The co-production phase unfolds predominantly during the contracted project (Stage 3) delivery phase, where the collaboration between researchers and policy organizations is most active. While this phase can also result in changes to the project specification, it generally resembles a project plan adjustment at this stage. The project manager then coordinates the delivery of the project and engagement between the researchers, project requesters and steering group. The final stage includes (Stage 4) output delivery and communication of results.

2.2. Data collection

This study focuses on the creation of a research program-level ToC, using empirical research. The ToC development process followed a mixed-methods approach involving online interviews and surveys with research program management and project staff, researchers contributing to the center's projects and external partners and beneficiaries, combined with analysis of secondary data and participatory workshops between December 2021-March 2022. This method aims to reveal the developmental processes that underpin research impact (e.g., Wagoner, 2009).

This multi-stage process for systematically gathering empirical evidence and creating a ToC involved a combination of inside-out and outside-in perspectives. The following types of data were collected and analyzed to create a program-level ToC.

1. *Online fact-finding interviews with research program representatives.* We conducted fact-finding interviews with 18 participants ($n = 8$ male, $n = 10$ female), including members of the research program's management team ($n = 7$), external strategic advisors that were part of a steering group for the research program ($n = 3$), and researchers that have worked with the center to develop impact or projects ($n = 8$). These focused on specific steps that have been taken with the aim of developing impact (including any intermediary or multi-stage flows for impact), and the specific benefits developed for society or nature as a result. These interviews provided the starting structure for preliminary theories of change at an overall center and project-level.
2. *Online scoping survey with project researchers.* An online mixed methods survey was developed, using categories established in prior empirical research on impact pathways based on research data (Jensen et al., 2022; Jensen and Reed, 2019, 2022). The survey was sent to research representatives and external partners and beneficiaries from 60 projects to identify impacts that have arisen from the center's activities. Overall, 84 respondents completed the survey and gave information relating to 34 unique registered projects. 59 % ($n = 43$) of respondents had held external roles in the research program's projects, while 47 % ($n = 34$) had been researchers on such projects (note: participants could hold multiple roles and not all respondents answered every question). This data was analyzed to provide a broad overview of the kinds of impacts arising across the research program, identifying common types of engagement and impact, and identifying patterns where possible. This scoping survey informed development of the preliminary theories of change at the research program level.
3. *Online structured qualitative interviews with external project partners and beneficiaries.* Finally, to ensure all major impacts and the contributory factors for such impacts are clarified, a purposive sample of seven key external project-level partners and beneficiaries was identified from information gathered within the fact-finding interview stage and support from the research program. Interviews were successfully conducted with 6 participants ($n = 4$ male, $n = 2$ female). These interviews explored key impacts in greater depth. The structured qualitative interviewing data also addressed key aspects of the research questions, with transcription of relevant content and thematic analysis designed to augment and underpin the theories of change.
4. *Online participatory workshop with external partners and beneficiaries.* Data collection with this external partners' group concluded with an online co-creation workshop with 7 participants ($n = 4$ male, $n = 3$ female) at which preliminary findings were presented and discussed, to inform the interpretation of results for the final report and paper.
5. *Online participatory workshop with research program staff.* We also convened a participatory workshop with 5 research program staff, including project managers and senior managers ($n = 1$ male, $n = 4$ female), who were invited to further discuss and add additional insights on impacts extending from the initial fact-finding interviews. The aim here was to fill in any missing pieces of the puzzle for a program-level ToC.

2.3. Data analysis

This mixed methods approach aims to leverage triangulation by bringing together different kinds of data and diverse perspectives on a shared focus. Triangulation involves integrating multiple techniques in a way that enables one method to offset the limitations of another, thereby reducing gaps in the analysis (Jensen and Laurie, 2016).

This set of mixed methods included descriptive statistics generated from survey data, as well as different forms of qualitative data. The qualitative data were analyzed systematically by trained social science evaluators, using a grounded theory analysis approach (Glaser and Strauss, 2017). To create an evidence-based visualization of the findings, the social scientists in the team worked with a graphic designer, piecing together initial findings and then iteratively refining the visualization and supporting results write-up based on iterative feedback from participants. This participatory approach to refining the analysis improved precision and reduced gaps in understanding between the research team and participants through an iterative process of discussion and refinement of visualizations until consensus was reached that representations were accurate.

Developing a research program-level ToC required building up a picture first at the project level, then identifying recurring patterns that could be generalized to the program level. These patterns were then linked to larger change processes (e.g., Jensen and Wagoner, 2009) through the analysis. The end result was a comprehensive program theory of change diagram, as well as quantitative and qualitative findings that extend from that diagram.

2.4. Limitations

Despite the comprehensive mixed-methods approach, this study has several limitations that should be acknowledged. First, the sample sizes for interviews and workshops were relatively small, and participants may not fully represent the diversity of experiences and perspectives within the program, potentially limiting the generalizability of the findings. Second, reliance on voluntary participation introduces self-selection and response biases; those who chose to participate might have had particularly positive experiences or were more engaged with the program, which could skew the results. Third, the assessment of impacts primarily relied on self-reported data without corroborating these perceptions with objective measures such as actual policy changes, implementation rates, or environmental outcomes. This reliance on subjective perceptions may not fully capture the extent or effectiveness of the program's impacts.

3. Results

Results from the scoping survey are presented first in this section, to provide an overview of the program and its policy impact activities. This information was integrated with qualitative findings to create a ToC for the overall research program, which is presented next.

3.1. Survey findings

3.1.1. Impact awareness and beneficiaries

To ascertain awareness of potential project impacts, respondents were asked, "Are you aware of any impacts that this project has developed for its beneficiaries?". In total, 55 % ($n = 42$) respondents indicated that they were aware of project impacts, while 18 % ($n = 14$) did not recall any impacts. 26 % ($n = 20$) respondents were unsure about whether impacts had been generated for the project they were responding about. Of the 34 unique projects that were registered in the survey, 68 % ($n = 23$ projects) were identified as having developed impacts by at least 1 respondent.

When asked "Which types of institutions or organized bodies directly benefited from this project?" on this 'tick all that apply' question, almost all participants responded 'the *Government and its agencies*' (95 %, $f = 36$). Much smaller proportions reported benefiting *HEIs/Research Institutes* (32 %, $f = 12$), *Industry / for profit business (inc. utilities not run by government)* (26 %, $f = 10$) and *Non-profit organizations* (24 %, $f = 9$). Specific policy-related institutions that benefited most often from this research program's projects that survey respondents were involved in were *SEPA* (74 %, $f = 29$), *Scottish Government* (56 %, $f = 22$), *Scottish Water* (41 %, $f = 16$), and *NatureScot* (36 %, $f = 14$).

3.1.2. Types of impact and timelines

In the next section of the survey, respondents who indicated that they were aware of impacts generated through the research program's projects were asked to provide additional detail on these impacts. First, they were asked "What types of impact has this project helped to develop?". Of all types of impacts, practice or capacity-building was the most frequently mentioned (68 %, f = 28), followed by government policy (61 %, f = 25). About half of the projects were reported to have generated general public awareness and natural environment impact (49 %, f = 20, each). Approximately one third were said to have impacted institutional policy (32 %, f = 13), and one quarter public health (27 %, f = 11).

For those respondents who indicated practice or capacity-building impacts, follow-up questions inquired about the specific nature of these impacts. Within this overarching category, an overwhelming majority was specified as improved understanding or awareness of a problem (89 %, f = 24). Moreover, about three quarters were categorized as informed organizational decision-making and improved understanding or awareness of potential solutions (74 %, f = 20, each). 41 % (f = 11) of the practice impacts were changed organizational practices or methods, while enhanced professional skills, knowledge or expertise and improved organizational structures, culture and/or communication flow each took up one third of the impacts (33 %, f = 9).

In turn, when organizational decision-making impacts were indicated, another follow-up question asked about additional detail. Most decision-making impacts were operational or technical (79 %, f = 15), while 68 % (f = 13) was strategic or management-related decision-making and 63 % (f = 12) decision-making related to regulations or policy.

3.1.3. Impact generation pathways

Next, respondents were able to report how the impacts were generated, that is, which factors contributed to benefits from projects for beneficiary organizations. The research program's project management expertise was the most prominent contributing factor (81 %, f = 38) to project impacts. Researchers and policy organizations collaborating *during* project delivery was the next most important impact-enabling factor (78 %, f = 36), followed by the practical value of research findings (77 %, f = 36). The research program's perceived credibility and the value of findings to plug knowledge gaps contributed to 72 % and 71 % (f = 31; n = 37) of the identified impacts, respectively. Making research findings particularly accessible as well as facilitating policy organizations engagement with each other enabled impacts to a similar degree (69 %, f = 34; 68 %, f = 30). Respondents indicated that the policy awareness and communication skills of researchers was a contributing factor in 60 % (f = 27) and 59 % (f = 27) of the identified projects' impacts, respectively. About half of the project impacts were additionally enabled by the research program's dissemination approach (51 %, f = 23). Researchers and policy organizations collaborating *before* the project contributed to impacts slightly less (46 %, f = 21).

To provide a comprehensive picture of the impact pathways, respondents were also asked about concrete project outputs and activities that helped deliver the project impacts. Of all output or activity types, report or summary information using findings was indicated for nearly all project impacts (98 %, f = 45), and more than two thirds of the impact-generating outputs were knowledge exchange or dissemination activities (70 %, f = 32). If respondents indicated report or summary information as the impact-enabling project output or activity, they were shown a follow-up question about the specific type of report/information. This showed that the main report (86 %, f = 35) was most likely to have contributed to impact, followed by the research summary (50 %, f = 21) and a policy note/brief (29 %, f = 11) based on the report, and other outputs.

Similarly, when respondents indicated a knowledge-exchange or dissemination activity as an impact-delivering project output, they were asked to specify the type of activity. Project meetings facilitated by the research program were the most frequently indicated knowledge-exchange activities (71 %, f = 20). Presentations at webinars or conferences were slightly less common (61 %, f = 17), and advisory or working group meetings as well as policy or management discussions each contributed to nearly half of the knowledge-exchange or dissemination activities (46 %, f = 13; 43 %, f = 12).

The majority of survey respondents had shared findings from the research program's projects with their networks (84 %, f = 27). Findings were most commonly communicated internally (85 % (f = 22) indicated that they mostly passed findings on to people within their organization who were not directly involved in the project, followed by people outside of their organization not directly involved in this project (77 %, f = 20), and people within their organization directly involved in this project (65 %, f = 17). When asked about the means through which they communicated with others about the research program's projects, most participants indicated they communicated through informal sharing of project outputs (74 %, f = 17), while communication through formal sharing of project outputs (57 %, f = 13) and informal communication of personally summarized project findings (43 %, f = 10) were less common. Of the respondents that indicated they used formal processes to share project information, policy or management discussions were used by half of respondents (50 %, f = 6). Presentations at webinars or conferences were also relatively common (42 %, f = 5), as were knowledge-exchange workshops (33 %, f = 4).
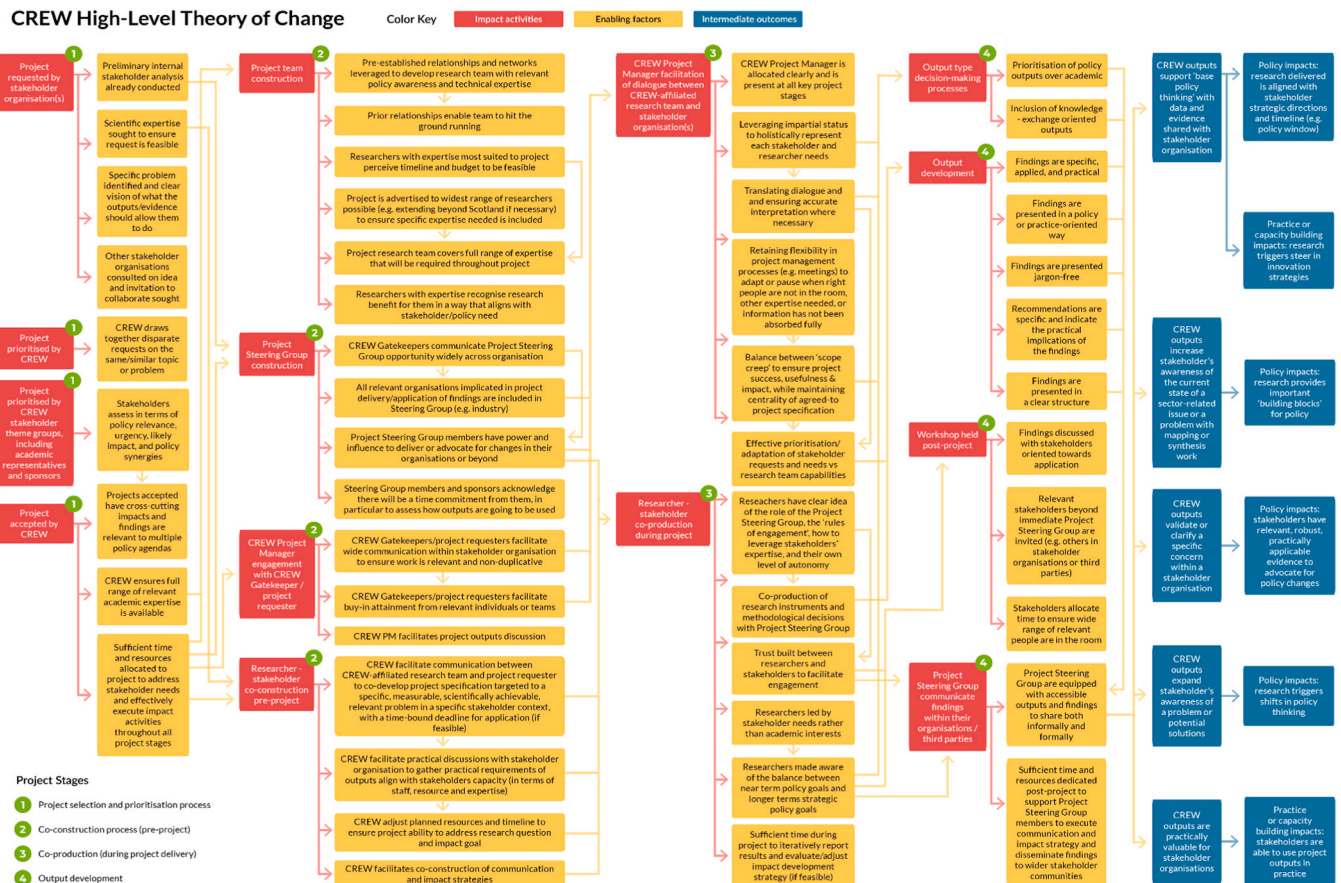
3.2. Research program-level theory of change (ToC)

The ToC diagram in Fig. 1 describes impact activities, enabling factors, and outcomes that were linked to impact development from the research program's projects, drawing from both survey results (see previous section) and interview findings (detailed in the following two results sections). Impact activities were defined as steps, output or processes within a project that help generate impact. They describe the nature of the intervention, the means, or the impact generating activities that take place within each stage of a project's life cycle. These stages include a proposed project's selection by the research program with input from policy organizations to guide prioritization (1), its construction (2), delivery (3) and communication (4). Enabling factors were defined as the characteristics relating to the step, output or process within a project that explain why it helped to achieve impact.

Research program impacts were split into two categories: (1) Intermediate outcomes are the demonstrable or perceptible new outcomes with individuals, groups, organizations and society linked to the project; and (2) Long-term outcomes are the demonstrable or perceptible benefits or impacts of particular new outcomes or changes linked to the project.

Fig. 1 shows how the research program has the capacity to facilitate impact at every stage of a project's life cycle (enabling factors are discussed in detail later):

- *Project selection and prioritization.* During the first project phase, we identified four key processes that served as foundational impact activities. The first was the project requesting process, followed by the research program's prioritization and theme group prioritization of projects to be accepted.
- *Co-construction process (pre-project).* These activities laid the foundations, in different ways, for co-designing the project, for example via preliminary work with relevant policy organizations to construct the project steering group and achieve buy-in of all relevant parties pre-project (Ferrier et al., 2022). Considerations around the availability of necessary academic expertise also feed into project team construction. Adequate time and resources for this collaborative phase can also determine the research program's project managers' ability to fully engage with those requesting the project or other relevant parties to ensure information flow with the project team.

Fig. 1. Theory of change for the research program level (image credit: Daniela Martin, Institute for Methods Innovation).

- *Co-production (during project delivery).* The collaborative work undertaken by researchers and policy organization representatives to ensure the specification meets policy needs and is scientifically feasible is further developed through researcher-policymaker co-production during the project. In addition, the understanding that the research program's project managers develop about the policy organizations' needs in the prior co-construction phase enables them to facilitate dialogue between the research team and policy organization(s) during project delivery.

- *Output development.* Well-executed prior efforts to prioritize policy needs and adapt them to the research team's capabilities, as well as co-production of research instruments and methodological decisions enable the development of outputs that are likely to lead to impacts. Continually acknowledging policy organizations' needs during this process ensures they will be equipped with relevant and shareable outputs that allow them to communicate the findings within their organization and to third parties in their networks. If sufficient time and resources have been allocated to the dissemination of these outputs, information flow is facilitated by a workshop held post-project with relevant policy organizations.

- *Outcomes and impacts.* When practically-oriented outputs or findings that sufficiently fill evidence gaps are taken forward and used in policy contexts, several kinds of outcomes can develop. Where outputs reactively support policy organizations' urgent, strategic 'base policy thinking' around an issue, policy outcomes can develop because of the research being delivered within narrow policy windows - much faster than it would take using longer procurement processes. In situations where the research program's outputs increase policy organizations' awareness of the current state of a sector-related issue, this type of work can be an important 'building block' for policy development. In other cases where research

program outputs validate or clarify a specific concern within a policy organization, policy professionals can use this kind of practically applicable evidence to advocate for policy changes. Where outputs expand policy organization representatives' awareness of a problem or potential solutions, by revealing new dynamics or issues not considered before, this can trigger shifts in policy thinking. Finally, where outputs have clear practical value, such as methods, manuals, or toolkits, this most often leads to practice or capacity building impacts, where policy professionals can use project outputs in practice.

3.3. Common enabling factors

This section draws on interview data to identify key common factors that have enabled impacts to develop from the wide portfolio of projects covered by this research program. Enabling factors are defined as the characteristics of a particular activity, process or output that make it successful as a step towards impact. These factors are discussed below in connection with different stages in a project life cycle.

3.3.1. Project prioritization and selection

Projects could be proposed by relevant policy organizations and were reviewed and strategically prioritized for funding. Project requests that were based on previous internal consultation by the requesting policy organization were more likely to enable impact, for example avoiding duplication of efforts and identifying synergies with ongoing work by the requesting policy organization and other relevant parties in their networks.

Impactful project requests also depended on the quality and specificity of research identified to answer a question or deliver impact, ensuring projects were technically feasible. This was a challenge for

some policy organization representatives who were aware that they did not have the "specific scientific knowledge to then come up with some of the questions that [the research program] answers" and therefore "rely on [key public sector organizations] quite heavily" (external participant, interview). As part of this, the research program often helped identify researchers with specialized expertise to help develop projects, or facilitated informal conversations with researchers prior to project specification.

3.3.2. Co-construction process (pre-project)

Wide advertisement of the project opportunity (beyond Scotland, if necessary) was critical to ensuring the right research expertise was attained for projects. This facilitated the research program's capacity to "identify quickly the relevant research expertise" (external participant, survey) and bring together a "group of researchers with complementary skills that may not have otherwise worked together" (researcher, survey).

The most impactful project teams often had pre-established working relationships. This included prior relationships between researchers, and between researchers and relevant external parties, resulting in early trust building within a project, which supported meaningful external engagement and buy-in.

Impactful steering group construction was enabled by research program gatekeepers communicating the opportunity to join it widely across their organization, as well as proactively considering third parties (e.g., specific industry partners) that may be relevant. Project steering groups were most impactful when their construction took into account the level of power and influence individuals had to take the project outputs or findings forward to make changes within their organizational contexts or beyond, for example, "if we hadn't had such senior individuals in the steering group, it might not have had the impact that it did because the people [...] were in a position to make others take note of what we were doing" (researcher, interview).

The research program's project managers were also crucial mediators during the project co-construction process between researchers and relevant external parties. They were often pivotal in helping narrow a project down to solving a highly specific problem in a specific context, with a clear, time-bound impact roadmap defined for generating project outputs. They were also crucial in the co-construction of impact strategies. Participants from outside the research program noted that projects were most successful when outputs and impacts were agreed at the start of the project.

Researcher participation in co-construction often results in reconfigured understandings regarding project feasibility in terms of resources allocated. In one example, a researcher "realized that the policy request could not be answered to deliver an outcome with impact with this budget" (researcher, survey). In these cases, impact is only enabled if necessary adjustments to timelines and resources are facilitated - "[...] eventually, the project used [over double the original budget], all time and budget needed to cover the policy need" (researcher, survey).

3.3.3. Co-production process (during project delivery)

Impactful co-production between researchers and external policy organizations during projects was typically facilitated by the research program's project managers, who acted as "honest brokers" (external participant, workshop). They leveraged their impartial status to challenge, translate and mediate between researchers and requesting policy organizations to ensure continued common understanding and clear communication of needs. This was particularly valued by external policy participants who recognized "it's a really important role that you wouldn't get if [the research program] wasn't there and if you directly commissioned research" (external participant, workshop). Impactful project management in the research program's projects was also sufficiently flexible and adaptive to changing needs, adjusting the scope of the project to ensure its impact without losing sight of the original specification: "Scope creep is often a feared word... but it's often a way

that a project has the most success. It's a balancing act" (project manager, interview).

In-depth engagement between researchers and project steering groups stimulated trusting working relationships between these groups, helping the research team become aware of, respect, and be led by the explicit policy needs. Sufficient time for iterative reporting of project progress was important, enabling "improve[ment to] the research iteratively during times of data collection and reporting" (researcher, survey) via continuous feedback. This leads to richer understandings of research users' contexts and opportunities to adjust the original impact development strategy, if needed.

3.3.4. Output development, communication and dissemination

As outputs were developed, efforts to ensure findings were presented in a way that meets the policy organizations' needs were essential for impact. In some contexts, this might include acknowledging policy professionals lack the time to read long outputs and adjusting length accordingly. However, policy professionals may also be communicating to third parties who "want greater depth, and not just a summary", and need extensive detail to justify changes to regulatory decisions or convince other specialists about the value of the work, so "at least being able to point at the evidence is useful" (external participant, interview). It was also recognized that "other resources or means of communication" such as GIS story maps or manuals are often more valuable for knowledge exchange than reports are for policy participants.

Reports needed to ensure findings were specific, practical, and applied to the policy or practice context of relevant parties for the research, with recommendations highlighting the practical implications and actions for specific audiences. When sharing with third parties, this would enable them to say, "here's the stuff that applies to you directly [...] corporates and managers just want to know what's their bit, what do they need to do" (external participant, workshop). The accessibility of these outputs was also crucial, in terms of a clear structure and plain English language for non-expert research users, to achieve a "balance of accessibility and precision" (external participant, workshop).

The research program-facilitated workshops held post-project were most impactful when they focused on ensuring practical application of project findings. Impact was most likely to arise from these workshops if a wide range of relevant parties were represented beyond the immediate project steering group. Project steering groups often facilitated this process, with one policy participant recalling that "the [project steering group] had obviously done a really good job of getting loads of relevant colleagues [...] lots of people from [a key government organization] there. [...] One of the regulatory leads said, 'we're reviewing just this area of work at the moment and we'll use this report to inform how we regulate in future'" (external participant, workshop).

Impacts were also dependent on the time and resources dedicated to sharing project findings. Many survey responses reported that "several" (researcher, survey) knowledge exchange or dissemination events helped enable impact including scientific presentations at conferences, webinars, policy engagement events and training sessions. Researchers also facilitated output dissemination by leveraging their "network connections" (project manager, survey) including "on social media [...] to carefully target beneficiary audiences" (researcher, survey).

A range of knowledge and skills enabled impact, including:

- *Researchers' communication skills* were highlighted as a crucial enabling factor for impact. During project delivery, this involved understanding policy needs well enough to "only ever really present [...] results that are essential or important" as this is what has "really helped" key government agencies using the program's research in the past (researcher, survey). Writing skills were important, for example being able to write for policy audiences or linking findings to specific policy contexts or recommended actions. Some participants also noted researchers' social media communication skills as an enabling factor of impact, as it allowed them to "carefully target

beneficiary audiences (e.g., other agencies, NGOs and researchers" (researcher, survey).

- *Researchers' policy awareness* and understanding of the project's relevance enabled them to "make sure that as the project […] develop[s], it [is] relevant at different levels, at different organizations" (project manager, interview).

3.4. Common barriers and missed opportunities

This section sets out common challenges and barriers to generating impact that researchers and policy professionals have faced, structured around the project cycle, based on interview data.

3.4.1. Co-construction process (pre-project)

Much of the co-development of proposals was pre-award and so not pre-planned and budgeted by the external policy organizations. Lack of budgeted time and project management capacity during the co-construction phase may have compromised dialogue and planning for impact, as "it can take a long time to go from having an idea to getting it to a project brief" (external participant, interview). For researchers, this issue was compounded by the need to adjust project specifications to meet policy needs throughout the project cycle, for example if "there's a very hard deadline we have to do everything by […] if there is any need for change of the scope, […] engage or re-engage with stakeholders, or find new broader stakeholders" (researcher, interview).

Lacking systematic analysis of relevant parties for the research caused major barriers to impact throughout project delivery, including wasted time, the need to reframe project scope in a way that risks the suitability of the research team, lack of external participant engagement due to shifting project ownership, and reduced likelihood of the project delivering useful outputs. For example, in one project "there was limited discussion going on with other parts of Scottish Water […] once they got wind that this project was happening and it crossed over quite a bit into stuff they were already doing, it then of course created an… interesting situation" (researcher, interview). Analysis of relevant parties for the research was done informally by the research center as part of the pre-award co-construction of projects, ensuring relevant organizations were involved in the development of initial project briefs and relevant steering group members appointed early in this process. However, without systematically analyzing the relative interest, influence and potential impacts for different organizations and groups across the water sector, there was a danger that hard-to-reach groups who could benefit significantly from the research program were not sufficiently engaged, and certain individuals (e.g., gatekeepers) and staff grades (e.g. more senior staff) and their expertise and interests were over-represented compared to others within their organizations who may have been able to make valuable contributions to projects.

Similar problems can occur if there was a lack of scientific input at the project design stage, as project managers may not always be able to fully "understand the work (time, expertise, staff) needed to deliver a project" (researcher, survey) meaning major adjustments may be needed as researchers become part of the conversation and raise concerns around feasibility and scope.

While policy organization-driven project requests with narrow specifications were most likely to generate impact, this conflicted with researchers' incentive to deliver projects that had potential for publication in top journals, while also narrowing the pool of suitable researchers in terms of specific expertise needed. This is because the measures of success in academic departments conflict with those within a project. The applied, impact focus of the research program means that many projects are unlikely to deliver original new knowledge that would be considered significant in an academic disciplinary context, and as a result it may be difficult to publish papers from many projects. Where publication of papers is possible, the Scottish focus of projects limits the international relevance of findings, limiting the caliber of academic journals they can be published in. This is less of a barrier to early career researchers who are building their publication profiles, compared to more senior researchers who are judged more on the quality of their outputs, with the Research Excellence Framework (REF) only providing financial rewards for internationally significant research outputs.

The co-construction process sometimes made it difficult to retain the coherence and focus of a project brief. Several interviewees highlighted that while having "multiple stakeholders sitting in a group" maximizes potential for wide ranging impact, "people might want different answers" (external participant, interview), resulting in too many or too broad questions. This may also reduce the project's potential impact as findings are more likely to be "inconclusive […and] the outcome you get at the end of a project mirrors that" (external participant, interview).

3.4.2. Co-production process (during project delivery)

One barrier to impact repeatedly highlighted throughout this review was that during the co-production process, "projects often become more focused on academic interests" (external participant, interview). This significantly affected the perceived quality of researchers working on the research program, the quality of the work itself, trust between researchers and policy professionals, and directly reduced impact, because "if it goes too far off the brief, we can't use it" (external participant, interview). This was a particularly significant issue when policy organization representatives had already been "very specific and […] clear about how we're going to use it" (external participant, interview). As well as reducing the likelihood of impact, this negatively affected researcher-policy professional dynamics, and could mean policy organizations were "increasingly […] less likely to use [the research program] because of this issue" (external participant, interview). Although the pressure to publish in top journals may be less acute for research institute researchers than senior academics in the higher education sector, this pressure exists across all career stages and types of research institution due to promotion and candidate selection criteria which prioritize publication profiles.

However, where changes to the project scope are genuinely needed, a key barrier to impact is the burden of "re-writing of the scope" being placed on the research team, a process some researchers said was based on vague statements from the policy organizations requesting the research. With limited guidance or input directly from policy professionals to the re-specification process, successive iterations of the scope in one project missed the mark, wasting project delivery time.

3.4.3. Output development, communication and dissemination

In terms of outputs themselves, several policy professionals noted that recommendations were often based on a very 'academic view', and there was a perception that the guidance the research program provided on writing for policy was not followed, placing further burdens on project managers to rigorously quality assure work and remind researchers of policy writing principles. While much of this issue of "researchers […] struggl[ing] with writing for policy" (project manager, interview) is likely a skills issue, we also found evidence of misunderstandings between researchers and the research program's project managers around 'what the policy organization wants' from project outputs, particularly in longer projects. This can lead to differences in opinion regarding appropriate output lengths, where some researchers may perceive that policy organizations will "not get a lot out of it" (researcher, interview), if they only produce short reports. On the other hand, project managers are driven by the perception that policy professionals find value in having findings concise enough to fit on one sheet of paper that could be handed to decision-makers "to potentially have 3 s of their time to scan over" (project manager, interview).

Many other barriers to impact at this stage can be traced back to a lack of proactive strategic planning around project output communications and impact. There was a perception that "even [in] successful projects […] that generate really useful tools or information, […] working out the best way to disseminate… is a massive challenge" (external participant, workshop). It was particularly challenging to

ensure project findings were communicated "beyond the orbits of stakeholders and researchers […] immediately circulating projects" (project manager, interview). Without this, the projects may have missed the potential for disseminating to a "much wider audience who could also take learning from that project" (external participant, interview) and "interaction […] with the wider water community" (researcher, interview). This could connect with the perceived lack of time and resources allocated for communication and impact within projects. Survey respondents noted "more time to disseminate results" (external participant) and "funding available to respond to the report" (researcher, survey), as aspects that would have been needed to better communicate project findings and develop impact.

3.4.4. Barriers across the project cycle

The analysis revealed a variety of issues tied to particular roles and responsibilities. First, there was a conspicuous absence of resources, roles, or responsibilities specifically allocated for the creation of project impact strategies. This essential step was rarely outlined in detail during the project specification phase, which resulted in project managers bearing this responsibility during the project. Their capacity to develop or implement impact plans, especially in short-term projects, was significantly limited. Furthermore, the potential for impact was not consistently evaluated as a part of project prioritization. There was minimal training or guidance provided to those designing projects to establish credible impact plans. As these plans were not systematically integrated into the project specification, the necessary resources for generating impact were often overlooked.

Secondly, a range of misunderstandings, capacity issues, and commitment levels in policy organizations were identified as hindrances to achieving impact. These issues were particularly evident in these organizations' roles as members of project steering groups and as gatekeepers for the research program. One project manager voiced their frustration, stating that "some of them I perceive don't do anything with the information […]. That's very frustrating […] to try and realize impact and communicate the project and get wider engagement" (project manager, interview). These issues adversely affected both project dissemination and the effort to connect research team members to project steering groups.

Lastly, several policy organization representatives in senior roles pinpointed their struggle to fulfill project steering group responsibilities due to a lack of resources. They shared that they "just haven't had the resources […] to actually get involved" (external participant, interview). Consequently, there is a prevailing perception that the research program's requests are impractical. These requests, such as "two weeks to come with comments on a sixty-page report", are considered unrealistic as they often find themselves being asked to perform similar tasks by "five or six people asking the same thing in the same two-week period" (external participant, interview).

Harnessing resources from all relevant parties involved and clearly defining roles for project impact strategies can pave the way for more efficient project execution. Enhancing mutual understanding and commitment within policy organizations further supports this goal.

4. Discussion

Previous research and professional analyses have revealed important limitations in the design and implementation of the ToC concept in practice. For example, an analysis by CGIAR (2012) found a "wide range of quality and adequacy of the theories of change through to impact". Moreover, this report recommends, "If the TOC has been constructed by a very small group (or even a single manager), those individuals may also take responsibility for updating it, but may need to put in place systems within their wider team for gathering data and evidence for the update" (CGIAR, 2012). Here, a wider team within the organization is foreseen as the broadest level of consultation to feed into a ToC. In this article, we have shown the potential for broadening the base of evidence

to feed into a theory of change as a way of delivering dual aims: more robust prospective impact planning and effective retrospective impact assessment.

In addressing the first aim of more robust impact planning, this study identified significant steps that could improve the research program's impacts in the future, which are likely to be applicable in other research and policy contexts. Identifying such pathways to program improvement is the primary purpose of a ToC. Undertaking the theory of change process using empirical research methods, instead of the traditional theoretical discussion with an internal team, allowed for a more precise, fine-grained understanding of the dynamics at work in the program's impact. As such, the ToC and supporting results from this study offers a blueprint for other research programs to intentionally develop and help realize their impact, particularly in terms of public policy and practice.

Romao et al. (2023) found similar benefits, in their review of ToCs that had been informed by empirical data, typically internal institutional data, literature review and external consultation data (similar to the sources used in the CREW ToCs). Although the ToCs reviewed by Romao et al. (2023) were only used for prospective impact planning (rather than evaluation purposes), they identified the need for ongoing data collection to update ToCs, showing how ToC can be continuously improved through data-driven insights. Although not explicitly using ToC methods, Bullock et al. (2021) also showed how empirical methods can enhance the relevance of policy outcomes in ToCs through a critical interpretive synthesis of 86 documents, which they used to create a theoretical framework for policy implementation.

While broadening the stakeholder base in ToC development and ensuring regular updates are crucial for capturing diverse perspectives and enhancing research impact, we acknowledge that this can be challenging in practice due to constraints such as stakeholders' limited availability, funding limitations, and varying levels of interest among researchers who may prefer to focus solely on their work. In our study, we encountered these challenges and addressed them by implementing flexible and efficient engagement strategies. We utilized online surveys and virtual interviews to allow participants to contribute at their convenience, minimizing time commitments. We also leveraged existing meetings and communication channels to gather input without over-burdening stakeholders. To encourage participation, we emphasized the mutual benefits of involvement, highlighting how their insights could inform future practice and enhance the relevance and impact of the research program. By being mindful of stakeholders' time constraints and demonstrating the value of their contributions, we were able to incorporate diverse perspectives into the ToC development process. We suggest that future initiatives consider adopting similar strategies—such as flexible engagement methods, clear communication of benefits, and integration with existing activities—to overcome practical challenges in broadening stakeholder involvement and adapting practice based on regular feedback.

Most outcomes identified in this study were capacity-building impacts that supported operational or technical decision-making, followed by actual changes in policy, regulation and guidelines, primarily for key public policy-related bodies in Scotland (including Scottish Government, SEPA, Scottish Water and NatureScot). Survey results showed that reports and project meetings were key mechanisms for generating impact, with project participants from policy organizations informally sharing findings more widely with their networks to increase reach. However, findings from interviews and workshops indicated that the impacts were highly dependent on several factors. The research program-level ToC identified key stages in the project cycle where impacts were facilitated, including:

- Early and on-going commitment to co-production processes from senior policy professionals with decision-making power, resources, and influence in their organizations, who are intimately involved in the commissioning process, ensuring a focused project scope which is

closely aligned to specific organizational contexts including strategic priorities and end user needs.

- Early inclusion of scientific expertise, ensuring the project scope is feasible within the allocated time and resources (provided it does not convey unfair advantage in the tendering phase).
- A strong foundation of trust between policy professionals and the research team, enabled by shared understandings and delivery of robust research that prioritizes policy organizations' needs.
- Co-production of research instruments and methodological decisions.
- Project outputs developed with a focus on the usability and practical applicability of findings.
- Longer projects with larger budgets were associated with greater levels of impact.
- The research program's existing policy organization-led model, which ensured research was co-produced as far as possible, and so were relevant to end use in policy and practice.
- The research program's existing reputation as a highly responsive, agile, and credible knowledge broker to deliver timely and impactful outputs that can feed directly into policy and practice.
- Project managers as boundary-spanners who were able to help translate and mediate between both policy needs and research findings to co-construct projects efficiently (cf., Greenhalgh et al., 2010).
- Having impact-enablers in a project group (whether positioned in researcher, end user or facilitator roles) who were able to leverage expertise, influence, and connectedness within and outside of their ability to help realize impacts.

The program's model of co-production, underpinned by strong policy-research collaboration, enabled it to deliver timely and relevant impacts. The mechanisms listed above, enabled the co-production of diverse and multi-layered impacts across different levels of governance, including micro-level effects on local policy-makers in addition to macro-level influences on national policy. The importance of co-production in the generation of policy impacts has been widely discussed. For example, Beckett et al. (2018) discuss the potential for co-produced research to generate both immediate and long-term outcomes, offering insights into how research can be integrated into policy and practice through iterative processes, similar to those used by CREW. They also emphasize the capacity for co-produced research and impact to contribute towards less obvious impact on relationships, knowledge sharing, culture shifts and capacity-building for future collaborative research. A critical theme in this study and the wider literature, underlined by the current study, is the role of trust in the co-production of impact. For example, Van der Graaf et al., (2021) highlighted the importance of trust and shared understanding between researchers and policy professionals to build capacity to use public health evidence in local government, drawing on the concept of "absorptive capacity" (Cohen and Levinthal, 1990; Lane et al., 2006) as the ability of organizations to effectively integrate new knowledge, echoing the focus on capacity building as one of the primary impacts arising from CREW.

4.1. Methodological implications

This study breaks new ground in the systematic and empirical development of evidence-based theories of change for research impacts, particularly focusing on policy outcomes. This methodological approach, using theory of change (ToC), represents a significant advancement in the field of research impact evaluation of programs over a long timeframe, an area where such practice is under-explored in the existing literature.

Here, we investigated an entire program to understand the dynamics of research-to-policy impacts. Our methodology involved piecing together a series of project-level theories of change, creating an inter-linked network of theories that culminated in an overarching program-level model. The construction of these theories was based on an array of overlapping evidence sources, ensuring a comprehensive and robust evaluation. This process required the integration of both inside-out and outside-in perspectives, enabling us to triangulate our understanding of the complex pathways leading to policy impact.

By adopting this innovative method, we have established a robust and adaptable framework that is of significant value for both evaluating and planning future research impacts. This framework holds particular promise for policy-related changes, offering an evidence-based approach to guide research planning and evaluation. Our findings underscore the importance of considering multiple perspectives and evidence sources in understanding research impact pathways, contributing to more effective and impactful research strategies in policy domains.

This research revealed that larger projects with extended timelines often yield greater impact. This aligns with prior studies showing long timeframes are often required for research impacts to fully mature. A recent study found an average time lag of 10 years from publication of research to impacts being realized (Stevenson et al., 2023), building on previous studies suggesting time lags of up to 17 years for biomedical research (Morris et al., 2011) and 7–19 years for research from multiple disciplines (Vertigo Ventures, 2022). The scope of the present study was a 10-year funding cycle for the research program, suggesting that this ToC-based empirical research method has the potential to capture impacts emerging relatively early in the typical timeframe over which impacts emerge. The dominance of capacity building impacts in our analysis also suggests that early-stage impacts were being captured, which are likely to mature over the following decade, if monitoring and evaluation is continued. Such methodological innovation is needed to better align our impact evaluation tools with the complex, long-term dynamics that enable research to influence policy. Integrating retrospective impact evaluation with forward-looking impact planning has the potential to enable strategic, evidence-based research impact praxis.

CRediT authorship contribution statement

EA Jensen: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation **S. Noles:** Writing – review & editing, Writing – original draft, Visualization, Investigation **MS Reed:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation **P. Lang:** Writing – review & editing

Declaration of Competing interest

The authors have no conflict of interest and the authors would like to convey "MSR was the CEO of Fast Track Impact (fasttrackimpact.com), and EAJ is the CEO of the nonprofit Institute for Methods Innovation (methodsinnovation.org) — both organizations provide training and consultancy services related to theory of change, policy engagement, and research impact".

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2025.104182.

Data availability

Data will be made available on request.

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